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(10) **CANADIAN PATENT**

(54) POSITION MEMORY SYSTEM

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This invention relates to a memory system for storing the position of objects as they move through a zone, and in particular it relates to a memory system for storing information as to the position of irregularly shaped objects with reference to arbitrarily defined locations.

The memory system may conveniently be used in apparatus for sorting ore to store information relating to the position of each piece of ore, and if desired to store other information concerning each piece of ore, as the pieces of ore move through a sorting zone. The invention will be described with reference to the sorting of ore, but it will be apparent that it could be used in other equipment and apparatus where it is desired to store information on the position of various objects passing through a zone.

A type of short term memory associated with a scan is known in a counting system for counting particles. Here the field which is to be scanned is stationary and the scan makes repeated sweeps across the field as it slowly moves along the field in the manner of a scan in a television receiver. As the scan encounters a particle it stores this in a simple memory to ensure that if the succeeding sweep or sweeps of the scan encounter the same particle it will be counted only once. A particle is therefore counted only when the scan has passed it. It will be seen that while the position of a particle may be temporarily stored, the position of each and the approximate size of each is not stored. The memory system according to the present invention stores the lateral extent, lateral position, longitudinal extent and longitudinal position of objects as they move through a zone.

According to one embodiment of the invention there is provided a position memory system for storing information relating to the position of randomly distributed objects as

the objects move through a sorting zone having at least three arbitrarily defined imaginary channels, comprising scanning means to scan across said channels and to provide first signals representing objects traversed by the scan, timing register means to provide second signals representing the instant of time at which a scan traverses the boundaries of said channels, a plurality of modules fewer in number than the number of said channels, arranged in a predetermined sequence and connected to receive said first and second signals, each module being adapted to handle information relating to one object and to remain associated with that object while the object moves past the scan, whereby the first module in the sequence not handling information related to an object will be receptive to signals representing the next object encountered for the first time by the scan, a number of storage register means equal in number to the number of said channels and each associated with one of said channels indicative of the lateral position thereof, each said storage register means being connected to every module, each said module being responsive to said first and second signals to select appropriate storage register means representing the lateral position and extent of the particular object being handled by the module and to pass to said appropriate storage register means a third signal representation of the longitudinal extent of the particular object being handled by the module, said third signal representation being retained in said storage register means and advancing along said storage register means at a rate related to the rate of movement of the particular object through said zone.

In another embodiment of the invention the position memory system is incorporated in a sorting apparatus and it stores not only the position of the objects being sorted but also information on several parameters associated with each

object so that the parameters may be assessed for each object, a decision made on whether to accept or reject the object, and a control signal passed to a rejection means to reject particular object in a certain position.

The invention will be described in more detail with reference to the accompanying drawings, in which

Figure 1 is a side view of a sorting apparatus with which the invention may conveniently be used,

Figure 2 is a partial end view of the apparatus
10 of Figure 1,

Figure 3 is a layout diagram indicating the layout or manner in which Figures 5 to 8 may be read together,

Figure 4 is a simplified schematic diagram useful in describing one embodiment of the invention in general terms, and

Figures 5 to 8 are schematic diagrams showing an embodiment of the invention in more detail.

For convenience in the following description, the term "pieces of rock" will be considered to refer to pieces or fragments which may be undesirable waste pieces, to pieces or fragments which may be desirable or valuable, or to pieces or fragments which contain both waste and a valuable constituent. Also in the following description the words "white", "whiter" and related words are used, and the words "black", "blacker" and related words are used. These words are used in connection with pieces of rock to denote relatively lighter and darker surfaces. In other words, a coloured surface may be referred to as having whiter areas and blacker areas, although the areas are not technically white or black.
20

In Figures 1 and 2 there is shown, in simplified form, a side view and an end view of a sorting apparatus with which the position memory system of this invention may be used. This type of sorting apparatus is known, and a
30

description may be found in Canadian patent application No. 39,451. A brief description of the apparatus will be given here to serve as a background for describing the present invention.

Referring to Figures 1 and 2, a hopper 10 is shown holding pieces of rock indicated at 11. The pieces of rock move downwards under the influence of gravity and are discharged onto a vibrating table 12 driven by a motor 14. Vibrating table feeders are well known. Pieces of rock 10 move along the surface of table 12 and are discharged at the end onto a second vibrating table 15 driven by a motor 16. The pieces of rock move along the surface of table 15 and are discharged at the end onto a slide plate 17.

The speeds of vibration of tables 12 and 15 are preferably independently adjustable for greater control of the feed. The tables are preferably adjusted to provide a closely packed but single layer of pieces of rock towards the discharge end of table 15. This will give an optimum rate of sorting.

20 The pieces of rock accelerate as they slide down plate 17 and are discharged onto a moving belt 18. The belt is moving at a speed greater than the speed of the pieces of rock being placed on it, and this serves to increase the spacing between individual pieces of rock. The belt 18 is supported by idler rollers 20 between a head roller 21 and a drive roller 22, and is cleaned by a spray 23 and rotating brush 24.

30 The pieces of rock 11 are moved by belt 18 past a scanning device 25 which makes repeated scans across the width of the belt and detects light reflected by the pieces of rock in the path of the scan. The apparatus assesses the reflected light and makes a decision which of the pieces are to be rejected. As the pieces of rock reach the head roller

21 they are discharged in a free fall trajectory past a rejection device 26. The rejection device 26 is shown as consisting of twenty air blast nozzles 27 in side by side relationship extending across the width of the path followed by the pieces of rock. Depending on the decision reached, one or more air blast nozzles may be actuated to direct a blast of air at a piece of rock and deflect it. The pieces of rock that are deflected by an air blast fall onto a belt 30 and the pieces of rock that are not deflected fall onto
10 belt 31.

It is necessary to isolate the scanning device 25 from the rejection device 26, and it is desirable that they be spaced or separated by a distance of several feet. A separation of several feet is desirable because air blast rejection generates some splash and mist which could interfere with the optical scanning.

It will be apparent that some means must be provided to remember the position of each piece of rock as it is scanned and to store this position as the rocks move along
20 the belt and past the rejection device in order that the correct air blast nozzles may be actuated and actuated at the appropriate time. It might be possible to have one memory associated with each air blast nozzle. This would require twenty separate memories with associated equipment for the apparatus of Figures 1 and 2. In such a system the output from the optical scan would be electrically divided into twenty portions. Each portion would be associated with an imaginary channel defined by one of the rejection devices whereby a piece of rock passing the scanning device and lying in one of the imaginary channels would remain in
30 that channel until it passed the respective rejection device. Thus, in such a system there would be a common optical scanning device, twenty devices to assess a portion of the

scan, twenty devices to decide whether or not a piece of rock should be rejected, twenty devices to remember the position of a piece of rock, and twenty devices to reject a piece of rock. It is doubtful that such a system would accurately handle the sorting of rocks which occupied two or more channels. In addition, such a system would be undesirable because the circuitry and apparatus is complex and expensive. It is desirable to keep the circuitry and the number of components to a minimum.

10 The present invention reduces the number of components by providing a series of modules, less than the number of imaginary channels, to assess and remember the position of each piece of rock. The number of modules required for a particular set of circumstances may be calculated. For example, from the anticipated range of rock sizes, belt speeds, rock spacing and scan speed it may be calculated that no more than eight rocks will ever be encountered in one scan, and therefore eight modules would be required for those conditions.

20 In the following description, reference will be made generally to the various edges of a piece of rock. To avoid confusion the terms "leading edge" and "trailing edge" will not be used. Instead, using the direction of movement of the pieces of rock as a reference direction, the edges of the rock in the longitudinal direction or direction of movement will be referred to as the front edge and the back edge. As the pieces of rock move they are scanned and the path of the scan traverses the pieces of rock substantially at right angles to the direction of movement. As the scan traverses the pieces of rock it will be assumed to move on to a piece of rock at its left edge and leave at its right edge. That is, looking at the apparatus as seen in Figure 2, the scan moves from left to right.

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Referring now to Figure 4, there is shown a simplified schematic block diagram of a sorting apparatus using the position memory system of this invention. A light detector and amplifier 32 receives reflected light from objects in the path of repeated scans across belt 18 as carried out by scanning device 25 (Figure 1). A suitable scanning device is described in aforementioned Canadian patent application No. 39,451. The output from the light detector and amplifier 32 is applied to a signal development circuit 34. A timing register 33 has a pair of photodiodes which are positioned in the path of the scan and provide a signal as the scan starts across the moving belt and a signal as the scan leaves the moving belt. In the simplified schematic the register 33 is shown providing two outputs. One output represents the time period when the scan is traversing a region where useful information may be derived, and this output is applied to signal development circuit 34 to actuate it only during the desired time period. The other output consists of twenty signals, each representing one twentieth of the actual belt scan. This output, in effect, divides the path of movement of the pieces of rock into twenty imaginary channels corresponding to the twenty air blast nozzles 27. These twenty signals representing, in effect, the channel boundaries are on individual conductors in a cable 35 and are applied to a series of eight modules 37-44. The modules 37-44 are identical and form part of the position memory system.

The signal development circuit 34 receives a signal representing the time period of the useful scan and a signal representing the reflected light received by the light detector. The signal development circuit is actuated during the scan to provide a plurality of outputs, each output being a parameter of the signal representing reflected light. Six parameters are shown and will be described briefly hereinafter.

The outputs representing the six parameters are connected to selector switches 45 which enable an operator to put any desired output signal representing a particular parameter on any one or more of the six conductors 46 connected to modules 37-44.

A rock timing circuit 47 receives a signal from signal development circuit 34 and it provides two signals - one representing the left edge and one representing the right edge of each piece of rock traversed by the scan. ▷

10 These two signals are applied to each of the modules 37-44.

The modules 37-44 will be described more fully in the subsequent detailed description. Very briefly, as the scan sweeps across the belt 18 it will at some time traverse a first piece of rock. Module 37 will, in effect, lock onto this first piece of rock and will accumulate the values of the input signals from conductors 46 that are associated with the first piece of rock. That is, the values of the input signals from conductors 46 will be accumulated as each repeated scan traverses that first piece of rock. If the 20 scan encounters a second piece of rock while module 37 is locked onto the first piece of rock, then the signals representing the second piece of rock are passed to module 38 which locks onto the second piece of rock. If the scan encountered a third piece of rock the signals would be handled by module 39 and so on. When the first piece of rock has completely passed the scan, and module 37 has finished processing the signals associated with the first piece of rock, then module 37 is released and will lock onto the next piece of rock.

30 Thus, one of the functions the modules 37-44 carry out is to lock onto a piece of rock and integrate the values of the input signals representing the parameters for that rock. When the back edge of the piece of rock passes the

scan, the module concerned compares the integrated values of the parameters in a predetermined manner, and based on the comparison makes a decision whether or not the piece of rock should be accepted or rejected. In addition, each module 37-44 includes a memory capable of storing information representing the length of the piece of rock from front edge to back edge (i.e., the longitudinal extent), and of course information representing the size of the piece of rock from left edge to right edge (i.e. the lateral extent). It will
10 be seen that the information in the memory may be used to represent the length and width (or longitudinal and lateral extent) of each piece of rock. Because each module also receives timing pulses related to the scan, it is possible to determine the position of each piece of rock. If a piece of rock being handled by a particular module is to be accepted, the module does not provide any output signal. If the piece of rock is to be rejected, that module provides two output signals. One output signal from a module is directed to a particular one or more (depending on the lateral
20 extent of the piece of rock) of the gate systems 48. There are twenty gate systems 48, one for each air blast nozzle, but only three are shown to simplify the drawing. This output signal represents the lateral position and extent of the piece of rock. The other output signal from the same module is applied to each of the gate systems 48 and represents the longitudinal extent and longitudinal position of the same piece of rock.

When one of the gate systems 48 receives two signals, it actuates a respective memory 50 which is a
30 type of a delay system or register. For example, memory 50 may be a register in which the signal representing the length of the rock actuates a number of units corresponding to length, and this representation is passed down the

register to an output. The rate of movement of the register may be controlled by and related to the rate of movement of the piece of rock on the moving belt. Thus, the gate systems 48 and the memories 50 which may be referred to as a storage register means, carries or provides information on the lateral extent, lateral position, longitudinal extent and position longitudinally in the zone for each piece of rock to be rejected. It will be apparent that the system could be adapted to carry or provide information on the position of each piece of rock if it was desired to use it for a purpose other than sorting. When used as described for sorting the memories 50 provide an output to a respective air blast control 51 at a time when the respective piece of rock will be passing in front of the respective one of the air blast nozzles 27.

Suppose, for example, there is a small piece of rock being scanned and it is in such a position on the moving belt that it occupies only one of the imaginary channels, say the second channel from the left as shown in Figure 2. That is, this piece of rock will subsequently fall from the end of the moving belt in front of the second from the left of the air blast nozzles 27 as shown in Figures 2 and 4. Suppose further that this piece of rock is of such a composition that it will be rejected. Now, still with reference to Figure 4, as the back edge of the piece of rock passes the scan, the module handling that rock reaches a decision to reject the rock and the module provides two output signals. One of the output signals goes only to the input of the gate systems 48 of the channel second from the left and therefore represents a rock which does not extend beyond the imaginary boundaries of this channel. The other output signal goes to all the gate systems 48 and is of such a nature that the length of the rock is defined. Only the second from the

left of the gate systems 48 has the necessary combination of input signals, and therefore only this gate opens and places the length of rock information in the respective memory 50. As the piece of rock falls in front of the second air blast nozzle from the left, the respective control 51 actuates the air blast nozzle to deflect the piece of rock.

It will be apparent that most pieces of rock will not be wholly within one of the imaginary channels as defined by the air blast nozzles 27. That is, most rocks will be of a lateral size or width (left edge to right edge) that they will have at least portions which pass in front of adjacent air blast nozzles. This does not affect the operation. If such a piece of rock is to be rejected, the output from the module locked onto that piece of rock will be applied to an appropriate number of adjacent gate systems 48 to cause an air blast from adjacent air blast nozzles 27 extending over the width of the rock.

It is believed that the preceding description provides a general understanding of the invention. A more detailed description will follow with reference to Figures 5, 6, 7 and 8. Figure 6a shows a minor variation of the circuitry of Figure 6. The Figures 5-8 together form a schematic of one embodiment of the invention and they may be considered together as indicated in the layout of Figure 3. For ease of reading from one Figure to an adjacent Figure, terminals have been indicated at the appropriate edges of the circuitry of the various Figures.

Referring to Figure 5, there is shown a simplified block diagram of a portion of a sorting apparatus which develops the signals subsequently used by the position memory system of this invention. The circuitry shown in Figure 5 is similar to circuitry described in the aforementioned

Canadian patent application No. 39,451. A light detector 32a provides an electrical output representing the diffuse light reflected by pieces of rock and the moving belt supporting them as the scan moves across the scanning zone. The light detector 32a also provides an output as the scan traverses a white reference reflector (not shown). The light detector output signal is amplified by DC amplifier 32b and is applied to an area discriminator and squarer 52, a black swing discriminator and squarer 53, a white swing 10 discriminator and squarer 54, a white discriminator 55 and a black discriminator 56.

A timing register 33 has a pair of photodiodes which receive light at the beginning and end of each scan or other means may be used to provide a signal at the beginning and end of each scan. The timing register 33 provides three general sets of signals as outputs. The first set of signals consists of twenty gate signals each on separate conductors in cable 57. These gate signals are consecutive in time, and each gate signal represents one twentieth of the scan. 20 The cable 57 goes to terminal A and continues on the next Figure of drawings. The second set of signals is a train of timing pulses which are related to the gate pulses. For example, there may be eight pulses for each of the twenty gates plus a number of pulses to provide for timing of functions which occur before or after the scan. That is, the pulse train may include 160 pulses for the scanning period plus 24 additional pulses. The number of pulses is not significant as long as they provide suitable timing. The timing pulses are on conductor 58 and are available at 30 terminal O. The third set of signals from timing register 33 are gating signals which are applied to gate timing circuit 60 and amplifier stabilization circuit 61. The gate timing circuit 60 provides a gate pulse to area

discriminator and squarer 52 to gate it on for a time period corresponding to the time of the useful scan. The amplifier stabilization circuit 61 is connected to the light detector 32a and it is actuated as the scan passes a standard reflector positioned outside the range of the scan across the moving belt. It includes an automatic gain control circuit which stabilizes the peak white level of the light detector. The amplifier stabilization circuit is also connected to DC amplifier 32b and the amplifier is gated on 10 when the light detector 32a should be receiving no reflected light. It includes a black clamp circuit which stabilizes the baseline or reference level of the DC amplifier 32b.

A belt speed sensor 68 develops signals proportional to belt speed and these are available at terminal R for use in circuitry which will be described hereinafter. For example, the belt speed sensor 68 may be connected to the drive roller or drive motor. Preferably the belt speed sensor 68 may be a magnetic pick-up adjacent a portion of the belt, such as an edge of the belt, to detect the passing of 20 slugs of magnetic material fastened at spaced intervals to the belt. The output of sensor 68 would, in this case, be a series of pulses proportional to belt speed.

The area discriminator and squarer 52, which is gated on only during the scan across the moving belt, receives the main video signal from amplifier 32b and produces a square shaped pulse representing the time period between the scan moving onto a piece of rock and the scan leaving the same piece of rock. That is, the output pulse represents the lateral dimension or width of the piece of rock at the scan, and the sum of these pulses for one piece 30 of rock would represent the scanned area of that rock. The edge of the pulse which represents the left edge of a piece of rock is delayed slightly in the area discriminator

and squarer 52. This serves to have the apparatus ignore small chips, and in addition the delay is useful in a circuit to be described subsequently.

The output from the area discriminator and squarer 52 is shown applied as one input to each of the black swing discriminator and squarer 53, white swing discriminator and squarer 54, white discriminator 55 and black discriminator 56, and also to rock timing circuit 47 and one terminal of each of the selector switches 45.

10 The four circuits 53-56 are discriminator type circuits whose level of discrimination may be individually set. As shown the discriminator circuits 53-56 are connected to the output of area discriminator and squarer 52 to provide a gating signal to the circuits 53-56 to gate them on for the time the scan is passing over a piece of rock. While it may be convenient to have the four circuits 53-56 gated, it will be seen from the subsequent description that it is not essential in practice to gate all the four circuits. Each of the circuits 53-56 has applied thereto as an input 20 the main scanning or video signal from DC amplifier 32b.

The black discriminator 56 produces an output whenever the signal representing reflected light is blacker than a predetermined level. The output is a linear function of the blackness of the piece of rock and may be referred to as the black linear signal. The output from discriminator 56 is available on conductor 63 and thus at one terminal of each of the selector switches 45 and is also applied to squarer 62 which produces constant amplitude pulses corresponding to widths of portions of rock being scanned which 30 are darker than the discriminator level. The output from squarer 62, which may be referred to as the black squared signal, is available on conductor 64 and thus at one of the terminals of each of the selector switches 45.

Similarly the white discriminator 55 produces an output whenever the signal representing reflected light has a value above a predetermined level, that is whenever the signal is whiter than a predetermined level. It should be remembered that the white discriminator 55 is gated on only when the scan is actually traversing a piece of rock. The output from discriminator 55 is a linear function of the whiteness of the rock and may be referred to as the white linear signal. The output from discriminator 55 is available on conductor 65 and thus at one terminal of each of the selector switches 45 and is also applied to squarer 66 which produces constant amplitude pulses corresponding to widths of portions of rock being scanned which are lighter than the discriminator level. The output from squarer 66, which may be referred to as the white squared signal, is available on conductor 67 and thus at one of the terminals of each of the selector switches 45.

The white swing discriminator and squarer 54 operates in the same manner as the combination of white discriminator 55 and squarer 66. The level at which the discriminator is set may, of course, be different so that the outputs are not necessarily identical. Similarly, the black swing discriminator and squarer 53 operates in the same manner as the combination of black discriminator 56 and squarer 62.

It was previously mentioned that it is not essential in practice to gate all the discriminator circuits 53-56. For example, the black swing discriminator and squarer 53 produces an output whenever the signal representing reflected light is blacker than a predetermined level. As the belt is white no output will be produced while the scan is on the belt. Therefore there is no need to gate the black swing discriminator and squarer 53 when a

white belt is used, and likewise there would be no need to gate black discriminator 56. Obviously the reverse is true for the white swing discriminator and squarer 54 and white discriminator and squarer 55 and these must be gated with a signal from the area discriminator and squarer 52. Similarly, it is essential in practice to gate the black discriminators 53 and 56 when a black belt is used.

10 The outputs of swing discriminators and squarers 53 and 54 are fed to variable stretch circuits 70 and 71 respectively. These stretch circuits extend the pulse duration by an amount which may be set into the stretch circuits. The outputs of stretch circuits 70 and 71 are applied as inputs to AND gate 72 which provides an output only when there is a pulse present at both inputs. In other words, there is an output from AND gate 72 only when the main video signal swings from a predetermined black level to a predetermined white level within the stretch time, or from the same white level to the same black level within the stretch time. The rate of change from black to white, 20 or vice versa, which will produce an output from AND gate 72 may be altered by changing the stretch time. The output from AND gate 72 is therefore a number of pulses representing a "count" of the times the main signal swings from black to white and vice versa with a transition time less than the stretch time.

It will be apparent, for example, that when a black piece of rock is on a white belt, there would normally be a count at the beginning and at the end of the scan across the piece of rock. Neither of these counts represents changes of the reflectivity or colour on the surface of the rock, and it would be desirable to eliminate these two counts. The count which occurs as the scan swings from belt white to the black of the rock presents little difficulty.

The swing discriminator 54 is gated by area discriminator and squarer 52, and the swing discriminator 53 may be similarly gated or acts in the same manner as has been described. It will be recalled there is a small delay in the edge of the gate signal from circuit 52 representing the left edge of a piece of rock. Thus the white swing discriminator and squarer 54 is not gated on at the instant the scan passes from the belt onto the piece of rock. Consequently there will be no count when the scan moves from the white belt onto
10 a black piece of rock. However, this is not the case when the scan leaves the piece of rock, i.e. when the scan passes from a black piece of rock to belt white. There will be a definite interval between the time when the main video signal is dropping at the rock edge but is still above the white swing discriminator level and the time when the signal from the area discriminator and squarer 52 cuts off the white discriminator and squarer 54. Thus, as the scan passes from a black rock onto the white belt, the AND gate 72 will receive a stretched black pulse and a stretched white pulse.
20 This will produce an output or a count. The output from AND gate 72 is fed to a gated pulse delay circuit 73 which is gated by the area signal from the area discriminator and squarer 52. The delay in the gated pulse delay circuit 73 is adjustable and is set so that the count caused by the scan moving from a dark rock onto a white belt occurs just after the end of the gate signal from area discriminator and squarer 52. This serves to inhibit the count generated as the scan leaves a piece of rock. For each valid count a pulse is issued by the gated pulse delay circuit 73 and
30 is available on conductor 74 and one terminal of each of the selector switches 45.

It will be seen that there are six signals representing parameters of the rock being scanned and each is

available at one of the terminals of the selector switches 45. The center or common terminal of each selector switch 45 is connected to the manually operable selector arm which may be moved to a terminal carrying any one of the six signals. The selector switches are set so that the desired signal is available at terminals B, C, D, E, F and G. The same signal may, of course, be available at more than one of these terminals if desired.

As was previously explained, terminal A has available twenty separate signals on separate conductors of a cable and
10 these signals represent consecutive gates for twenty channels. The terminal O has available a timing pulse train. Terminals H and I carry signals representing the left edge and right edge of a piece of rock as seen by a scan.

Figure 5 shows circuitry which is common, that is only one is required in a sorting apparatus. Figures 6, 7 and part of 8 show circuitry in one of the eight modules. That is, the embodiment described would include eight similar groups of circuits but only one is shown in Figures 6, 7 and part of 8 for ease of illustration.

20 Referring now to Figure 6, it will be seen that the signals at terminals represented by A, H, I and O are not used in this portion of the circuit and are carried through to Figure 7. The signals at terminals B, C, D, E, F and G, which represent the selected parameters, are applied respectively to variable gated integrators 80-85. Each integrator 80-85 is gated on and off by signals applied over cable 86 from terminals J and K. To simplify the drawing a cable 86 has been used representing the conductors from terminals J and K. The signal at terminal J is an enabling pulse signal corresponding to the time scan across
30 a piece of rock, that is representing the time of scan from left edge to right edge of a piece of rock being scanned where the module shown is locked onto that piece of rock. The signal at terminal K represents the right edge and may be used to ensure integration is complete. The source of the signals

comparator could provide an output depending on the amount by which a first input exceeds a second and a low reference level if the first input does not exceed the second input. Thus, all the comparators may be arranged in a mode to provide outputs which are simple on/off outputs or they may be arranged to provide continuously variable outputs with reference to (b) or (c) as indicated above for (a).

The outputs from comparators 87, 88 and 89 are applied to comparators 91 and 92 as shown. Comparators 91 10 and 92 are similar to comparators 87-89, they may be set in the same manner and operate in the same manner. It will, of course, be apparent that if comparators 87-89 are set to work in the on/off or digital mode, then comparators 91 and 92 must work in the same mode. However, the outputs from comparators 87-89 may be in a continuously variable mode while comparators 91 and 92 are arranged to provide outputs in a digital mode.

In the embodiment shown in Figure 6, the comparators 91 and 92 are followed by AND gates 93 and 94 as will be described. The AND gates are suited to handling signals of a digital nature and consequently, in this embodiment the outputs from comparators 91 and 92 should be digital in nature. It should be emphasized that many arrangements of integrators and comparators may be made and this is a feature of the apparatus. It can be readily adapted to the characteristics of any ore and waste.

The output from comparator 91 is applied as one input to AND gate 93 and the output from comparator 92 is applied as one input to AND gate 94. The other input to 30 each of the AND gates 93 and 94 is via conductor 95 from terminal M. The signal at terminal M is a decision signal as will be described in connection with Figure 7. The decision signal available at terminal M enables the AND gates

93 and 94 at a time when a decision is required whether or not to reject the piece of rock being handled by that module. The outputs from AND gates 93 and 94 are applied as inputs to a final comparator 96 which may, in this embodiment, be an OR gate or an AND gate. Comparator 96 provides an output signal on conductor 97 if the piece of rock is to be rejected. The output signal on conductor 97 may be referred to as the blast signal, and it is available at terminal N.

10 It should be noted that many types of ore will not require six parameters as the basis for making a decision as to the value of each piece. In the majority of cases, four parameters will be sufficient, and in some cases three will be sufficient. It will be apparent that the number of components could be reduced where fewer parameters were used. For example, if four parameters were to be used there would be four signals representing these parameters which could be integrated by integrators 80-83, and the outputs could be compared on comparators 87 and 88 with their outputs going to 20 one final comparison stage 91. The blast signal would then be available as the output from the gate 93. Many variations are possible as a parameter may be used more than once in the comparison stages.

Referring briefly to Figure 6a, an alternative circuit arrangement is shown where the outputs from comparators 91 and 92 are applied directly to comparator 96a. The output from comparator 96a is in digital form and is applied to an AND gate 98 which is enabled by the decision signal from terminal M. As before the blast signal, which is 30 the output from AND gate 98, is available at terminal N.

As an aid to understanding Figure 7, the signals will be referred to by using a "0 level" or a "1 level", that is a binary type representation for a low signal level

and a high signal level. It will, of course, be apparent that many alternative arrangements are possible in the circuitry of this invention, and particularly in the circuitry of Figure 7.

Referring now to Figure 7, there is shown the circuitry which enables a module to lock onto a piece of rock and which provides the signals referred to previously with reference to terminals J, K, L, M and N. It is believed Figure 7 may best be described by considering its action and 10 operation as signals are applied to it under different conditions.

A module may be in one of three conditions at the instant the scan moves onto a rock at the left edge, as follows:

- (1) The module may be locked onto another piece of rock and consequently not available.
- (2) The module may be resting and waiting to lock onto the next available piece of rock if it is given the opportunity to do so.
- (3) The module may be already locked onto this piece 20 of rock and be waiting for the information from the scan across its surface which is just beginning.

The circuitry will be described with reference to each of the above conditions. The signals which are available are the timing pulses at terminal O; a signal representing the scan leaving each piece of rock, i.e. representing the right edge at terminal I; and a signal representing the scan starting across each piece of rock, i.e. representing the left edge, at terminal H. The signals at upper terminal A, representing the twenty channel signals, are not used by this 30 portion of the circuit and are carried by a cable to the lower terminal A and thence to the circuitry of Figure 8.

In condition (1) referred to above, the module is locked onto another piece of rock. As the scan reaches

the left edge of the piece of rock in question, there will be a signal at terminal H. This signal passes through all the modules in order as is indicated by block 100, shown in a broken line, representing the preceding module. The signal is passed through the preceding module and appears on conductor 101. The signal may be in the form of a pulse going from 0 to 1 and back to 0. It will be seen that the signal on conductor 101 is applied as one input to AND gate 102, as one input to AND gate 103, and as one input to AND gate 104.

10 A single shot multivibrator or SSM, shown as 105 has one output (indicated as the "one" output) connected as an input to AND gate 102 via conductor 130 and the other output (indicated as the "zero" output) connected as an input to AND gate 103 via conductor 129. SSM 105 is in its un-triggered or rest state, as will be subsequently described, because the module is locked onto another piece of rock. Therefore, there is no signal (i.e. a 0 level) on conductor 130 while there is a signal (i.e. a 1 level) on conductor 129. Thus, when a signal representing the left edge of a
20 rock appears on conductor 101 it does not alter the condition of AND gate 102 and the output from AND gate 102 will remain at 0 level. However, AND gate 103 has enabling signals at two of its three inputs as has been described, that is one representing the rock edge from conductor 101 and the other from SSM 105. The third input to AND gate 103 comes from the output of NAND gate 106. The purpose of NAND gate 106 is to ensure that the module does not lock onto a piece of rock if another module has locked onto it. Also NAND gate 106 is part of a circuit which prevents this module from
30 locking onto another piece of rock while it is still making a decision or resetting itself after handling a piece of rock. This will be explained subsequently. Because the module is locked onto another piece of rock the NAND gate 106 is in

such a condition that an enabling signal (i.e. a 1 level) is provided at the third input of AND gate 103. Consequently AND gate 103 is enabled and the signal representing the left edge of a piece of rock passes along conductor 107 to the next module.

In condition (2) referred to previously, the module is available and ready to lock onto a rock. It is assumed that the module described is the first available one and will be the one which locks onto the new piece of
10 rock.

The SSM 105 has not been triggered and remains in its rest condition. There is consequently a 0 level on conductor 130 connected to AND gate 102 and AND gate 102 does not pass the left edge of rock signal on conductor 101. However, the condition or state of NAND gate 106 has changed from that described in connection with (1) because the module is ready to lock onto a piece of rock. The output of NAND gate 106 is 0 and there is no enabling signal from it at the third input of AND gate 103. Therefore AND gate 103 does not pass the left edge of rock signal. An inverter 110 is connected to NAND gate 106 and provides an enabling signal (i.e. a 1 level) at one input of AND gate 104. The other input of AND gate 104 carries the pulse signal representing the left edge of a piece of rock. The AND gate 104 is enabled and its output goes from 0 to 1 and back to 0 in accordance with the pulse representing the left edge. It should be noted that the signal on conductor 101 and the resulting change of output of AND gate 104 at this time represents two things. It represents the left edge of a piece of rock being traversed by the scan, but because it is the first scan which traversed any portion of this piece of rock it also represents the front edge of the piece of rock.
30 Thus, the output of AND gate 104, which is available at terminal

P, may be used to represent the front edge of a piece of rock.

The output from AND gate 104 is applied as one input to OR gate 111. There is a 0 input from AND gate 102 and a pulse from AND gate 104 which causes a pulse output from OR gate 111 going from 0 to 1 and back to 0. The output is applied to flip flop 114, flip flop 115, and OR gate 116 via conductor 117. This output serves to trigger flip flops 114 and 115 to their "set" condition, i.e. it sets flip flops 114 and 115. When flip flop 114 is set it provides a 1 level output on conductor 118, and this is available as an enabling signal on one input of AND gate 120.

The flip flop 115 when in the set condition provides an output at terminal J and when it is in its reset condition provides an output at terminal K. The flip flop 115 is switched to its reset condition by a pulse signal from terminal I over conductor 122 which is common to all modules. The signal on conductor 122, as was previously discussed, represents the right edge of a piece of rock. Thus, the length of time that flip flop 115 is in its set condition represents the time that the scan spends traversing the particular piece of rock to which the module is locked, and it is the time interval for which the signals representing the various parameters should be integrated. The integrated signal is available at terminal J for use in the Figure 6 circuitry as previously described; and for use in the Figure 8 circuitry. A signal representing the end of the scan across the piece of rock (i.e. the right edge signal) is available, if desired, at terminal K for the circuitry of Figure 6 to ensure integration is completed.

Returning now to OR gate 116, it will be recalled that a signal was applied over conductor 117 which goes from 0 to 1 and back to 0. This serves to inject one count into a counter 123 which is arranged to be actuated by a single count after being reset. Counter 123 when actuated by a

count provides a signal (i.e. a 1 level) on conductor 124 to AND gate 120. The two signals on conductors 118 and 124 permit the train of timing pulses, available at terminal 0, to pass through gate 120. The train of timing pulses pass through OR gate 116 to counter 123. It will be recalled that the number of timing pulses have a fixed relationship with the scan. The counter 123 is arranged to count a predetermined number of the timing pulses and then provide an output to trigger SSM 105. The number of pulses counted
10 is set so that the scan has started its next sweep and is almost to the same lateral position where it encountered the left edge of the piece of rock on the previous sweep. Thus SSM 105 is triggered slightly before the scan reaches the position where it encountered the left edge of the piece of rock on the previous scan, and the time that SSM 105 stays in its triggered position is adjusted so that it returns to its untriggered state slightly after the position where the left edge of the piece of rock was encountered on its previous scan. In effect, SSM 105 provides a short time period
20 during which that module may receive the pulse representing the left edge of the same piece of rock on the next scan, and in this manner locks the module onto that piece of rock. During the time SSM 105 is triggered it provides an output at its terminal connected to conductor 130. This is inverted by inverter 125 to provide a 0 level signal on conductor 126. Conductor 126 is connected to conductor 127 which is common to all the modules, and when a low level or 0 signal is on conductor 127 all the other modules are inhibited from capturing (i.e. handling) any signal on
30 conductor 101. The conductor 127 may be said to carry a capture inhibit signal.

A capture inhibit signal or low level signal on conductor 127 inhibits other modules from capturing a pulse signal on conductor 101 because it is applied over conductor

128 to NAND gate 106. A 0 on any input to NAND gate 106 will cause a 1 output which is applied as an enabling signal to AND gate 103. Unless SSM 105 is triggered there will be another enabling signal at AND gate 103 and a pulse signal on conductor 101 will be passed, in effect, through that module to the next.

Now to refer to previously mentioned condition (3), it will be recalled the module is locked onto a piece of rock and waiting for the next scan across the surface of that piece of rock. Counter 123 has just finished counting and it then simultaneously resets and provides a signal to trigger SSM 105 and a 0 level on conductor 124. The 0 signal on conductor 124 ensures that the AND gate 120 is not enabled and does not pass the pulse train signal from terminal 0. With SSM 105 in its triggered state there is a capture inhibit signal provided on conductors 126 and 127 and there is an enabling signal (i.e. a 1 level) applied to AND gate 102 over conductor 130. Thus, the pulse representing the left edge of the piece of rock, when it arrives, will pass AND gate 102 and be applied to OR gate 111. Thus, the OR gate 111 has a 0 at the input connected to AND gate 104 and the pulse signal representing the left edge of a piece of rock at the other input. A pulse signal is therefore provided on conductor 117 to start the counting once more, and to trigger flip flop 115 to its set condition. The flip flop 114 is, of course, still in its set condition and remains there.

Now let us consider that portion of the circuit provided to handle the situation when the piece of rock to which the module is locked passes the scan. Suppose the module is in condition (1) where it is locked on to another rock and is counting the timing pulses. The module being locked to another rock is not responsive to this particular piece of rock passing the scanning zone. Its operation is as

before. That is, there is a 1 level on conductor 124 and because of inverter 142 there is a 0 on conductor 131. This causes a 1 output from NAND gate 106 and ensures that AND gate 103 is open and will pass signals to the next module as has been described. The reset portion of the circuitry remains inactive or quiescent. However, to provide a complete description, the remaining circuitry is given at this time and its operation discussed. Conductor 131 is connected as one input to NAND gate 132 and carries a 0 signal. The SSM 105 has not been triggered and there is a 1 level on conductor 129 and at the other input to NAND gate 132. The output from NAND gate 132 is a 1 level and this is applied to SSM 133. The SSM 133 is arranged to be triggered by a change from 1 to 0 at its input. In its untriggered or resting state SSM 133 provides a 0 level on conductor 134 and a 1 level on conductor 135. The conductor 134 is connected to terminal M and to SSM 137 while the conductor 135 is connected to AND gate 136 as one input. The SSM 137 is in its untriggered or resting state and consequently there is a 0 level on conductor 138 and a 1 level on conductor 140. Conductor 138 is connected to terminal L and conductor 140 is connected to AND gate 136 and to the reset terminal of flip flop 114.

The AND gate 136 has three inputs, and all have enabling signals at this time. The output of AND gate 136 is connected to a stretch circuit 141. The AND gate 136 is enabled and provides a 1 level to stretch circuit 141 and via 141 to NAND gate 106. The NAND gate 106 is not affected by this signal. As was previously explained, the 0 level on conductor 131 causes the output of NAND gate 106 to be 1 ensuring that AND gate 103 is open.

Now suppose the module finishes counting the timing

pulse as was described in connection with condition (3). With the completion of the counting SSM 105 is triggered and the signal level on conductor 124 changes. Just prior to this there was 1 level on conductor 129 and a 0 level on conductor 131. Now with the triggering of SSM 105 there is a 0 level on conductor 129 and a 1 level on conductor 131. It will be seen that the inputs to NAND gate 132 are reversed but they are still a 0 and a 1 level. Consequently the output from NAND gate 132 remains a 1 level and there
10 is no triggering of SSM 133 or SSM 137. However the situation being considered is where the particular piece of rock to which the module was locked has just passed the scan. Therefore no pulse signal appears on conductor 101 during the time interval that SSM 105 is triggered. Thus, SSM 105 resets changing the signal on conductor 129 to a 1 level. There are then two 1 levels at the inputs to NAND gate 132 and the output from NAND gate 132 changes from 1 to 0 level. The SSM 133 is arranged to trigger on this change and it provides a signal on conductor 134 which may be referred to
20 as the decision signal. This signal is available at terminal M and signifies that a piece of rock has been completely scanned and initiates circuitry for making a decision to accept or reject that piece of rock as was described in connection with Figure 6. Conductor 134 is also connected to the input of SSM 137 and SSM 137 is triggered when SSM 133 resets, i.e. when the signal on conductor 134 changes from a 1 level to a 0 level. When SSM 137 is in its triggered state it provides a signal on conductor 138 which may be referred to as the reset signal and which is available
30 at terminal L to reset the circuitry of Figure 6 for the handling of the next piece of rock. When SSM 137 resets, it also resets flip flop 114 to remove the module engaged signal from conductor 118.

During the time SSM 133 is triggered there is a 0 level on conductor 135 and consequently at one input of AND gate 136. During the time SSM 137 is triggered there is a 0 level on conductor 140 and consequently at one input of AND gate 136. When SSM 133 and 137 reset they provide a 1 level signal to these two inputs of AND gate 136. There is, of course, a 1 level signal on conductor 129 which is connected to another input of AND gate 136. Thus AND gate 136 is enabled and provides a 1 level output. However, stretch circuit 141 adds a small delay before it provides a 1 level signal to NAND gate 106. The delay provided by stretch circuit 141 ensures that all the circuitry has had time to reset, and then provides a 1 level output to NAND gate 106 causing it to provide a 0 level (assuming there is no capture inhibit signal on conductor 127), and this in turn will enable AND gate 104 to accept signals from the next available piece of rock. In other words, the circuitry is now as described in connection with condition (2).

Referring now to Figure 8, a line of division is indicated by a broken line 145. This line of division is intended to separate Figure 8 into two portions. The portion of the circuitry of Figure 8 which is to the left and above (as shown in the drawing) the line of division is circuitry associated with a module. The portion of the circuitry of Figure 8 which is to the right and below the line of division is circuitry common to the apparatus, that is, each of the eight modules is connected to this common circuitry.

In Figure 8 the terminals R, A, P, J, L and N are associated with the same signals as previously described in connection with these terminals. Considering first the transverse section, that is the section of circuitry which

provides signals to certain ones of the twenty channels across the diagram as seen in Figure 8, the terminal A has available twenty consecutive gate signals which are conducted by cable 147 to a series of 20 AND gates 150. Only the first two and the last one of the series of 20 AND gates 150 are shown for simplicity of drawing and they are designated 151, 152 and 153. Thus, an enabling gate signal is applied to a respective one of the series of AND gates 150 by a conductor in cable 147 so that the enabling signals are applied in sequence along the series corresponding to the position of the scan. The terminal J has the integrating signal for that module, indicating when the scan is traversing the piece of rock to which the module is locked and this integrating signal is applied over conductor 154 as an enabling signal to an input of each of the series of AND gates 150. Whenever there are two enabling signals at the inputs of one of the series of AND gates 150, the particular gate provides an output which sets the respective one of a series of 20 flip flops 155. Again only three of the series of 20 flip flops 155 are shown and they are designated 156, 157 and 158. It will be apparent that one or more of the series of flip flops 155 will be set when a module is locked to a piece of rock, and the flip flops which are set represent the number and location of imaginary channels occupied by the piece of rock as it moves through the sorting zone. The flip flops remain in their set condition until a reset signal appears from terminal L on conductor 160. It will be recalled that the reset signal is produced only when a module has completed the handling of a particular piece of rock.

Whenever one of the series of flip flops 155 is set it provides an output which is an enabling signal applied to one input of a respective one of a series of 20 AND gates 161. Again, only three of the series are shown and they are

designated 162, 163 and 164. The other input of each AND gate in the series of AND gates 161 is connected in parallel via conductor 165 to terminal N which has the blast signal. Thus, if the decision is to reject a piece of rock to which the module is locked, there will be a blast signal on conductor 165 and the gates in the series of AND gates 161 corresponding to the position and lateral extent of the piece of rock will be enabled. The gates which are enabled will provide a signal at an input to a respective one of a series of 20 OR gates 166. The OR gates shown are designated 167, 168 and 169. The series of OR gates 166 are common and thus there are eight inputs to each OR gate in the series (one from a respective AND gate in the series of AND gates 161 in each of the modules).

Before continuing with the description of the common portion of the circuitry, the description of the circuitry associated with each module will be completed. In each module there is a flip flop 171 having its set input connected to terminal P by conductor 172 and its reset input connected to terminal L by conductor 193. The output of flip flop 171 is connected to one input of AND gate 173 by conductor 174. The other input of AND gate 173 is connected to terminal R by conductor 175. Terminal R carries a source of signals representing the speed of belt 18 (Figure 1). As was previously mentioned a signal from the driving motor may be arranged to provide an appropriate signal, or preferably the belt may incorporate slugs of magnetic material evenly spaced along one edge so that they pass a magnetic pick-up or sensor 68 (Figure 5). Flip flop 171 is in its set condition from the time a piece of rock to which the module is locked first enters the scanning zone until it leaves the scanning zone. For this period of time flip flop 171 provides an enabling signal to AND gate 173, and the

output from AND gate 173 is the series of pulses from terminal R. The series of pulses from AND gate 173 may be called shift pulses and these shift pulses may be applied to a divider 176 to reduce the number and to keep the succeeding register to a convenient size.

The shift pulses, which are related to belt speed (i.e. speed of the pieces of rock past the scan), are applied to a register 177. The register 177 may comprise a series of flip flops (of which the first three have been designated 180, 181 and 182), arranged so that the shift pulses set the flip flops in sequence. That is, flip flop 180 is set, then flip flop 181 is set, then flip flop 182 is set and so on. It will be seen that the number of flip flops in register 177 in their set condition are proportional to the length of the piece of rock being handled by that module. Each flip flop in register 177 is connected to an input in a respective one of a series of AND gates 183. The other input of each of these AND gates is connected by conductor 184 to terminal N. Terminal N carries the blast signal.

When the blast signal is generated it provides an enabling signal to one of the inputs of each AND gate in the series of AND gates 183, and if a respective unit in register 177 is in the set condition a signal will be provided at an input of a respective one of a series of OR gates 185. The OR gates are designated 186-192. Each unit in register 177 is connected to terminal L by conductor 193. This ensures that the register 177 is reset when the module has finished handling the piece of rock.

The series of OR gates 185 are common and thus there are eight inputs to each OR gate in the series (one from a respective one in the series of AND gates 183 for each of the eight modules). Thus, there are a series of 20 OR gates 186 and a series of 7 OR gates 185, each of which

has 8 inputs.

In the common portion of the circuitry of Figure 8 there are 20 stepping registers of which only three are shown for convenience of drawing. These three registers are designated 194, 195 and 196. Each one of the registers 194-196 has a plurality of units determined by the belt speed and the distance between the scanning zone and the rejection means. The first seven units in the registers 194-196 are shown in full, the drawing of the registers is then broken, and a part of the last unit is shown. Only the register 195 will be described in detail as the 20 registers are all identical. The units in register 195 have been designated 200-207. The first seven units of register 195 are connected to the output of a respective one of a series of 7 AND gates 208. The series of 7 AND gates associated with registers 194 and 196 are designated 209 and 217. The AND gates in the series of AND gates 208 are designated 210-216 and each has two inputs. One input of each AND gate in the series of AND gates 208 is connected by a conductor 217 to the output of OR gate 168. The other input of each AND gate in the series of AND gates 208 is connected to the output of a respective OR gate in the series of OR gates 185. That is, the other input of AND gate 210 is connected to the output of OR gate 186, the other input of AND gate 211 is connected to the output of OR gate 187, and so on.

It will be seen that when the blast signal is available at terminal N it will appear on conductors 165 and 184 of any module and there will be signals at the outputs of certain ones of the series of OR gates 166 and 185. At certain of the AND gates in the 20 series of AND gates, of which 209, 208 and 217 are shown, a signal will be present at both inputs, thus enabling these AND gates. The AND gates

will, in turn, set the respective unit in the respective one of the 20 registers (of which 194, 195 and 196 are shown). At this time the units which are set in the registers will represent the lateral position, lateral extent or width, and longitudinal extent or length of the piece of rock. The registers are driven or stepped by the shift pulses used for register 177. Thus, the registers are arranged so they continuously step towards the remote end at a rate related to belt speed. It is important that the timing of the blast and its duration be locked to conveyor belt speed. As the set units in the registers reach the end of the register they actuate the respective ones of air blast control units 51. The air blast control units cause an air blast to be directed at the piece of rock as it passes the air blast nozzles.

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THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A position memory system for storing information relating to the position of randomly distributed objects as the objects move through a zone having at least three arbitrarily defined imaginary channels, comprising scanning means to scan across said channels and to provide first signals representing objects traversed by the scan, timing register means to provide second signals representing the instant of time at which a scan traverses the boundaries of said channels, a plurality of modules fewer in number than the number of said channels, arranged in a predetermined sequence and connected to receive said first and second signals, each module being adapted to handle information relating to one object and to remain associated with that object while the object moves past the scan, whereby the first module in the sequence not handling information related to an object will be receptive to signals representing the next object encountered for the first time by the scan, a number of storage register means equal in number to the number of said channels and each associated with one of said channels indicative of the lateral position thereof, each said storage register means being connected to every module, each said module being responsive to said first and second signals to select appropriate storage register means representing the lateral position and extent of the particular object being handled by the module and to pass to said appropriate storage register means a third signal representation of the longitudinal extent of the particular object being handled by the module, said third signal representation being retained in said storage register means and advancing along said storage register means at a rate related to the rate of movement of the

particular object through said zone.

2. A position memory system as defined in claim 1 in which the objects are moved through said zone on a conveyor belt.

3. A position memory system as defined in claims 1 or 2 including reset means to reset a module and make it available to associate with another object once it has passed its information to one or more storage register means.

4. A position memory system as defined in claim 1 in which the scanning means is a light scanning means which includes a light sensitive detector for receiving light reflected from objects traversed by the scan and which provides said first signals representative of the reflected light.

5. A position memory system as defined in claim 4 in which said scanning means includes means to derive from the reflected light a plurality of parameters and to provide information on said parameters as part of said first signal.

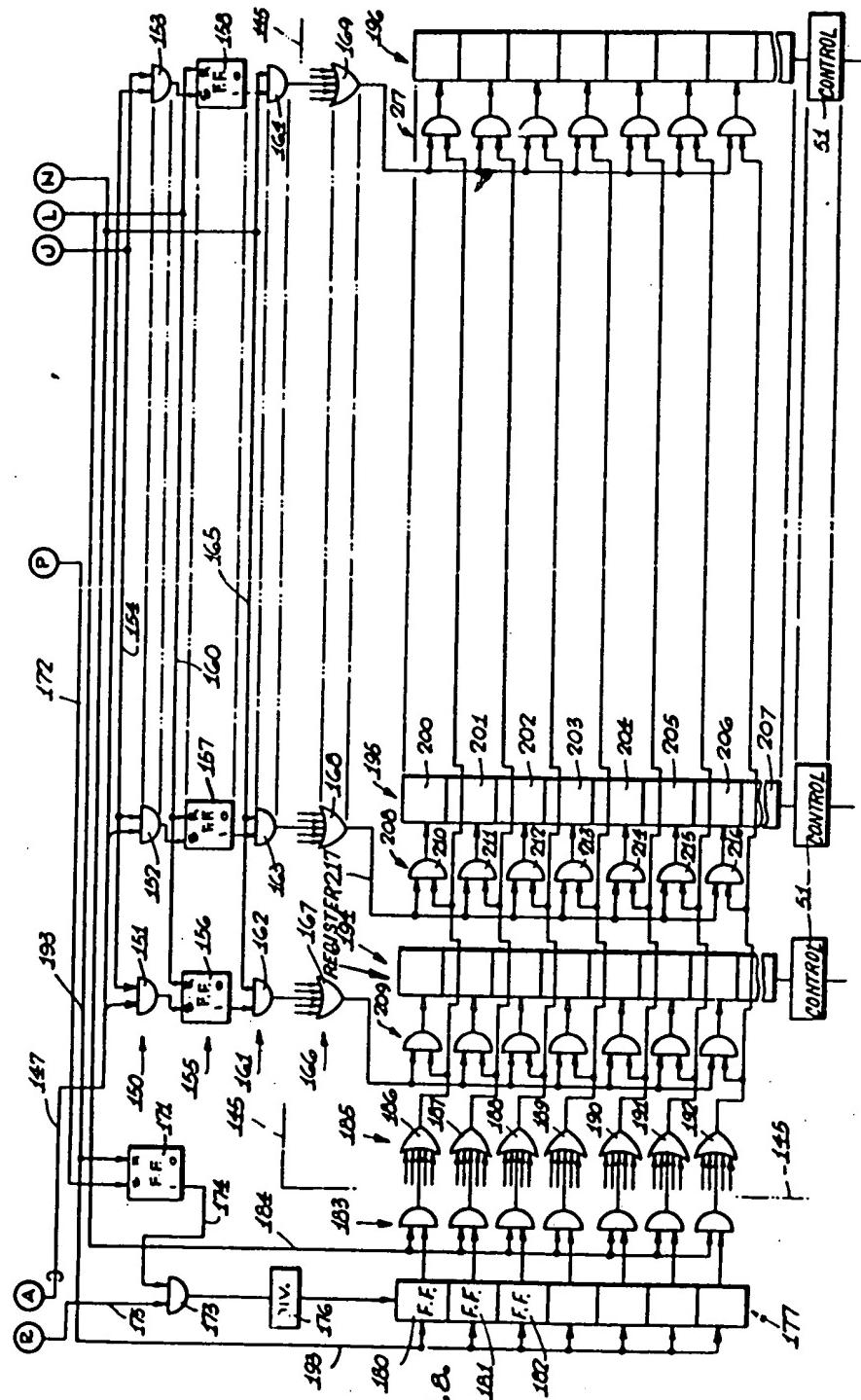
6. A position memory system as defined in claim 5 in which each module includes integrating means to integrate and store information on said parameters relating to the object with which the module is associated.

7. A sorting apparatus incorporating a position memory system as defined in claim 6 and further including a rejection device for each said channel, each rejection device being controlled by a respective storage register means to accept or reject an object, said modules each including means to compare said parameters in a predetermined manner and to provide said third signal only when an object is to be rejected,

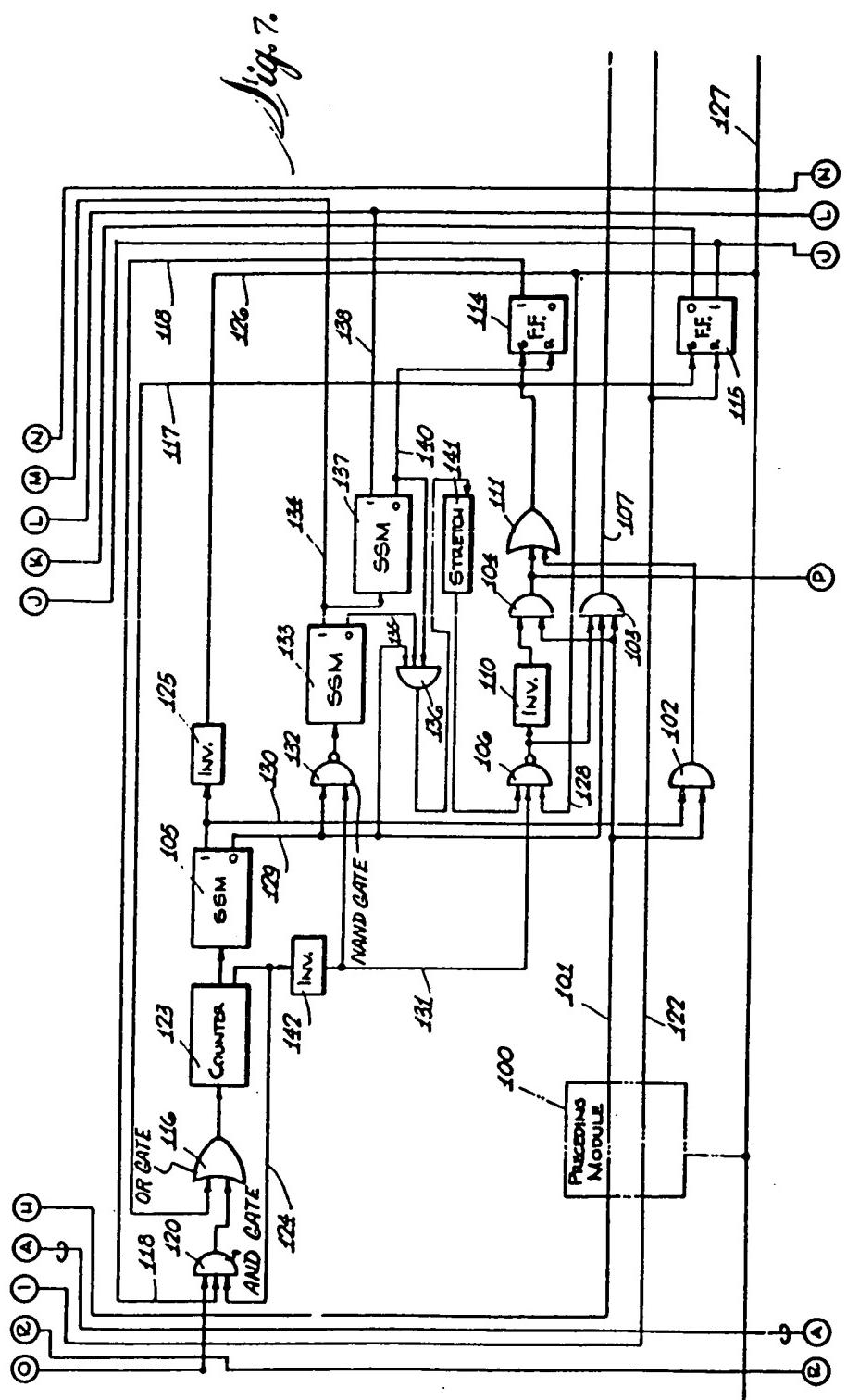
the representation of said third signal as retained in said storage register means actuating a respective rejection device to reject an object when said representation advances to a point in said register corresponding to the object moving past the rejection device.

8. A sorting apparatus as defined in claim 7 in which the rejection devices are a series of air blast nozzles extending across the zone in side by side relationship.

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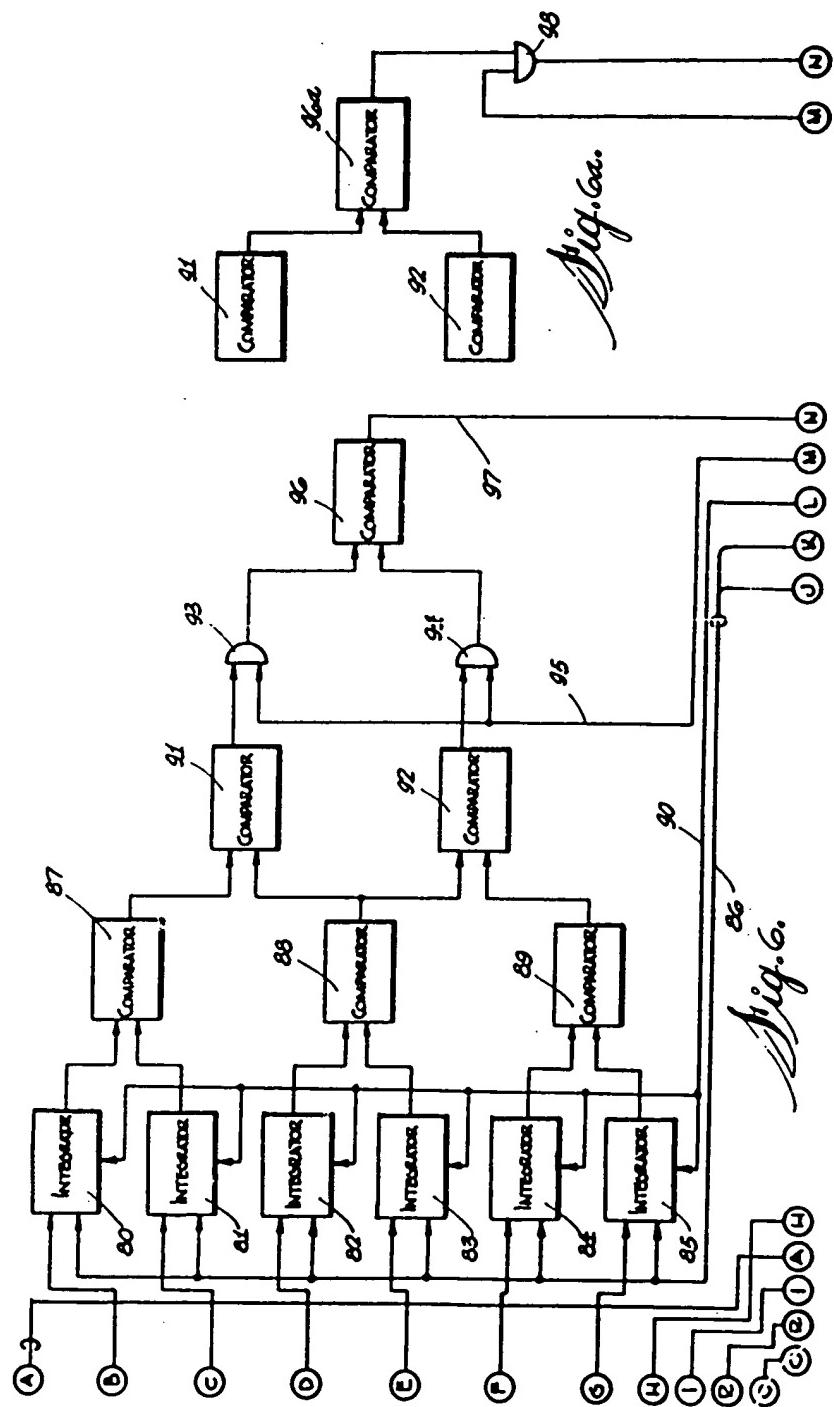
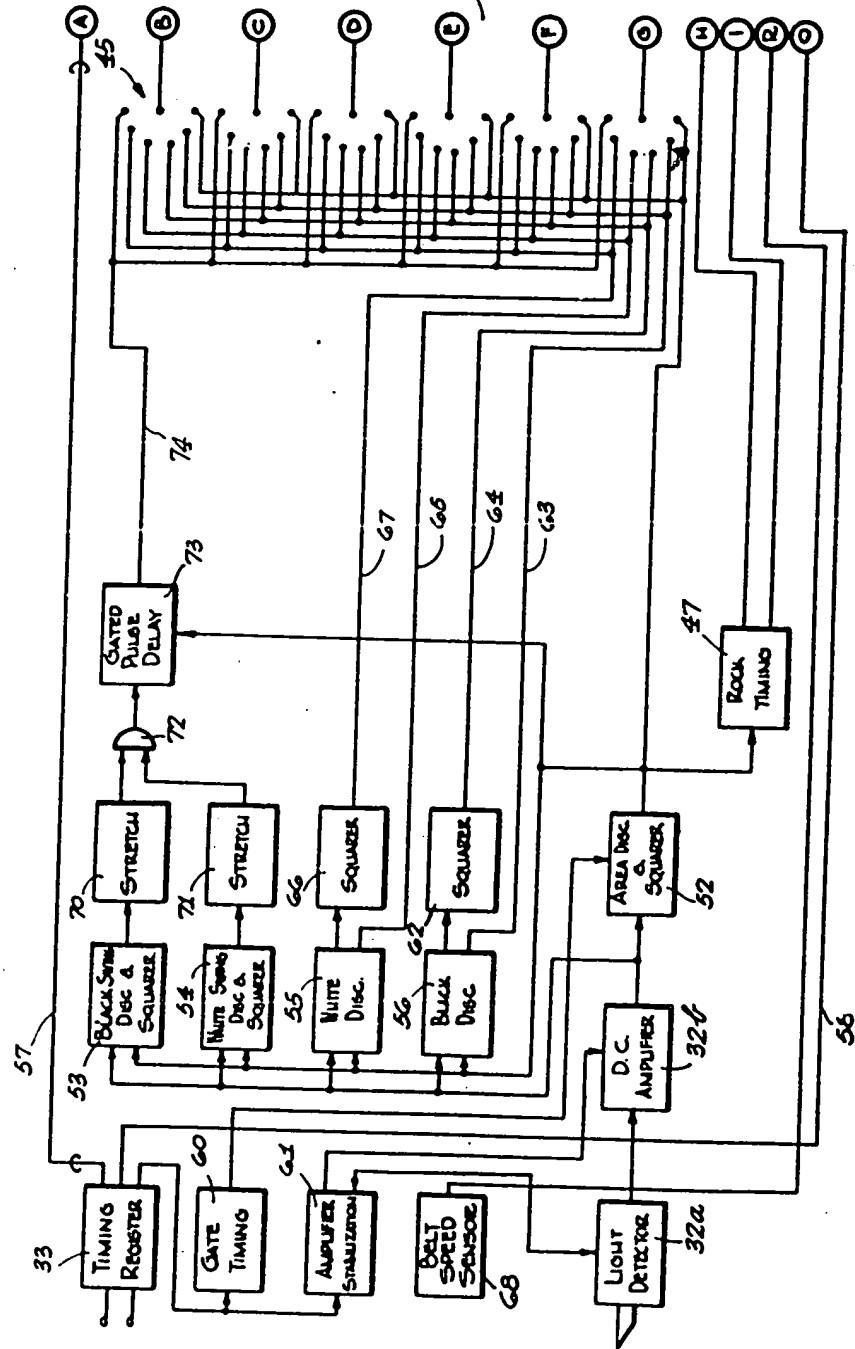


fig. 5.



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